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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

OF THE

PASADENA MEETING

AT THE

NORMAN BRIDGE LABORATORY OF PHYSICS

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

DECEMBER 8, 1928

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PASADENA MEETING, DECEMBER 8, 1928.

The 154th regular meeting of the American Physical Society will be held in the Auditorium of the Norman Bridge Laboratory at the California Institute of Technology, Pasadena, California, on Saturday, December 8. The morning session begins at 9:30 o'clock.

Titles and abstracts of papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction, they will be published in an early number of the Physical Review. Authors should send corrections to the Editor, of the Physical Review at the University of Minnesota, Minneapolis, Minnesota.

Other meetings for the current season are as follows:

155. December 27–31, 1928. New York City. Annual Meeting.

156. February 22–23, 1929. New York City.

157. April 26–27, 1929. Washington.

158. June 19–22, 1929. Pacific Coast Section. Berkeley.

L. B. LOEB
Local Secretary for the Pacific Coast,
University of California, Berkeley Calif.

PROGRAM

1. Analysis of the gradual oxidation prior to ignition of fuels in internal combustion engine and the relation of such oxidation to detonation. W. M. ZAIKOWSKY, H. B. HOLROYD AND V. M. SOKOLOFF, California Institute of Technology.—A study was made of the change in oxidation of gasoline-air mixture prior to ignition in the engine due to the admixture of 0.25 percent of lead tetra-ethyl. Non-doped mixture was found to undergo a greater oxidation. The difference is equivalent to 2 percent of the total oxygen present in the air-cooled engine. No increase of the compression pressure corresponding to such difference in oxidation was observed, what suggests oxidation is not homogeneous reaction. Study of oxidation of pure and doped gasoline-air mixtures in heated tubes was made. It was found that ethyl lead and other dopes reduce the rate of oxidation of gaseous explosive mixture in gaseous phase during a short time only, while oxides deposited on the tube walls remain continuously effective anti-oxidants. For the solid carbon, lead oxide is found to be distinctly a positive surface catalyst, in addition to the known fact that it is capable of oxidizing hydrogen and light hydrocarbons at relatively low temperature. The effectiveness of antiknock compounds is ascribed to the temporary elimination by them of O_2 molecules sufficiently activated to react with hydrocarbons directly and in this manner reducing activation of the initial products of oxidation of fuel molecules oxidized by the oxygen consumed by the antiknock.

2. Ionization of neon and argon by positive ion bombardment. RICHARD M. SUTTON, Norman Bridge Laboratory, California Institute of Technology.—In a tube of special design, positive ions of potassium from a Kunsman catalyst source were directed into neon or argon at various pressures. By variation of the accelerating potential, evidence of ionization of the gases by the positives was obtained commencing at approximately 100 volts. Definite variation of the effect with change of pressure was noted. Ionization was readily separated from secondary effects of emission of electrons from metal surfaces and reflection of positive ions; such secondary effects did not amount to more than 5 percent of the observed ionization. The number of new ions formed per positive ion impact is decidedly less than for electrons of the same kinetic energy. Attempts to ionize hydrogen by this process gave practically negligible results up to 750 volts, agreeing with the results of W. J. Hooper. Ballistic considerations show that a sharp ionization potential is not to be expected by this method of excitation.

3. The Photoelectric Effect of Liquid Tin and two of its allotropic Modifications. ALEXANDER GOETZ, California Institute of Technology, Pasadena.—The photoelectric emission of pure tin is measured over a range of temperature from 550° to room temperature. The red limit of the emission was observed to be considerably different for the liquid and the crystalline phase which indicates a qualitative parallelism with the change of the thermionic work function at the melting point of other metals. (A. Goetz, Zs. f. Phys. **42**, 329; **43**, 531, 1927.) Besides this change which goes together with a large decrease in intensity, there is also observed an alteration in the photoelectric threshold at the transition of the tetragonal (β) tin into the hexagonal (γ) tin. For each phase the photoeffect appears to be independent of temperature as long as one corrects the observed values for the change of the optical reflectivity with temperature. The photoelectric thresholds for the different phases as observed are: Tin liquid (232°–550°), 2910 ± 10A; γ-tin hexagonal (203°–232°), 2820 ± 10A; β-tin tetragonal (70°–150°), 2720 ± 10A. The transition from β-tin into γ-tin is found to be remarkably slow and shows an analogy to the well-known small transition—speed of the other allotropic change—β-tin into α-(gray) tin. This explains probably the discordant data of earlier authors who give—assuming the transition is like in other metals a sudden one—the temperature of the allotropic change between 203° and 100°.

4. The ionization of Cs vapor by light of frequency greater than the series limit. ERNEST O. LAWRENCE AND N. EDLEFSEN, University of California.—Using the space charge method of Foote and Mohler [Phys. Rev. **27**, 37–50, (1926)] we have studied the ionization of caesium

vapor by light of wave-lengths from the series limit to 2200A. We find that the ionization efficiency of the light falls off rapidly from the series limit to shorter wave-lengths, excepting for wave-lengths near 2536A (Hg line) where the efficiency is of the same order of magnitude as that of the series limit—in agreement with the observations of Foote and Mohler. However, the ionization efficiencies for wave-lengths on either side of 2536A are a great deal less than that of the Hg line, and therefore Foote and Mohler's extrapolation of the ionization efficiency to shorter wave-lengths is not valid. It is probable that the anomalous ionization by light of 2536A is due to the presence of a trace of Hg vapor. Williamson [Phys. Rev. **21,** 107 (1923)] and Lawrence [Phil. Mag. **50,** 345 (1925)] concluded that the ionization efficiency of light in potassium vapor increases rapidly to shorter wave-lengths. Recently Williamson [Proc. Nat'l Acad. **14,** 793 (1928)] has confirmed this conclusion. It appears therefore that caesium and potassium are not similar in behavior.

5. Momentum of photoelectrons in relation to the momentum of the ejecting x-rays. CARL D. ANDERSON, California Institute of Technology.—Photoelectrons ejected from a gas by x-rays have been studied by means of a Wilson cloud chamber. The κ rays of molybdenum and tungsten were employed and tracks obtained in air, hydrogen, argon and a mixture of hydrogen and argon. The momentum of the radiation was found to equal that of the photoelectrons if the average value of their forward components was taken as a measure of their momentum. This is in contradiction to the conclusions of Williams (Nature, **121,** 134 (1928)) and Auger (Compte Rendus, **186,** 758 (1928)) who find the momentum of the photoelectrons to exceed that of the radiation by 20–50 percent. The momentum, however, as calculated from the position of the peak of the longitudinal distribution curve, is in general, greater than the momentum of the incident radiation in agreement with the conclusion of Williams and Auger.

6. Probable values of the general physical constants. RAYMOND T. BIRGE, University of California.—A critical study of existing data yields, $c = (2.99796 \pm 0.00004) \times 10^{10}$ cm $\cdot$ sec^{-1}; $G = (6.664 \pm 0.002) \times 10^{-8}$ dyne $\cdot$ cm^2 $\cdot$ g^{-2}; liter $= 1000.027 \pm 0.001$ cm^3; $H = 1.00777 \pm 0.00002$; $He = 4.0022 \pm 0.0004$; $Ag = 107.880 \pm 0.001$; int. ohm $= (1.00051 \pm 0.00002)$ abs. ohm; int. amp $= (0.99995 \pm 0.00005)$ abs. amp; $A_n = (1.013249 \pm 0.000003) \times 10^6$ dyne $\cdot$ cm^{-2}; $A_{45} = (1.013199 \pm 0.000003) \times 10^6$ dyne $\cdot$ cm^{-2}; $\nu_n = (22.4141 \pm 0.0004) \times 10^3$ cm^3 $\cdot$ mole^{-1} $= (22.4135 \pm 0.0004)$ l $\cdot$ mole^{-1}; $T_0 = 273.18 \pm 0.03$°C; $J_{15} = 4.1852 \pm 0.0006$ abs. joules; $J_{20} = 4.1813 \pm 0.0006$ abs. joules; $J'_{15} = 4.1835 \pm 0.0007$ int. joules; $J'_{20} = 4.1796 \pm 0.0007$ int. joules; $F = 96489 \pm 5$ abs. coul. $= 96494 \pm 1$ int. coul; $e = (4.770 \pm 0.005) \times 10^{-10}$ abs. *es* units; e/m (spectroscopic) $= (1.761 \pm 0.001) \times 10^7$ abs. *em* units; e/m (deflection) $= (1.768 \pm 0.002)$; $h = (6.547 \pm 0.009) \times 10^{-27}$ erg $\cdot$ sec. Each constant is independent of those following, but may depend on those preceeding. Original results have been recalculated where necessary, using all auxiliary constants as here adopted.

7. Another Attempt to Find Directional Effects in Cosmic Rays. R. A. MILLIKAN AND G. H. CAMERON, California Institute of Technology.—With much improved technique and conditions of observation we have studied anew the intensity of the cosmic rays as a function of orientation with respect to celestial objects without bringing to light the slightest evidence of the existence of a directional effect of any kind. We conclude that if there be any directional effect at all it cannot produce a variation of more than two or three percent at the most in the intensity of the radiation in question.

8. Ion mobilities using the Erikson method on gases of controlled purity. JERRY J. MAHONEY, University of California. Introduced by Leonard B. Loeb.—Measurements of mobilities of ions in air and in air mixed with known quantities of other gases were made, using the Erikson air blast method under conditions where the nature of the purity of the gas could be reasonably controlled. The results show that there is no ageing effect in air dried over P_2O_5 and liquid air, or even in air passed slowly over $CaCl_2$. In these two cases the normal positive and negative ionic mobilities are observed. If air from the room of 60 percent or 90 percent relative humidity at 20°C is used the well known ageing effects of Erikson are observed. With mixtures of 5 percent and 25 percent HCl no ageing effects are observed. With 5 percent NH_3 the positive ion has the same mobility as the negative ion, but at ages over about 0.01

seconds both negative and positive ions show an apparent ageing, the positive ion going over to the usual value observed while the negative ion forms an ion having a mobility between the old and new positive ions. In pure C_2H_2 positive and negative mobilities were observed in agreement with those found by Loeb and Du Sault and Wahlin, while in dry air with 5 percent C_2H_2 normal air mobilities were observed with no ageing effect. It is concluded that the ageing of positive ions in general proceeds very much more rapidly than Erikson assumes and possibly consists in the attachment of the initial positive ion to a bulky molecule of some impurity present. Water vapor and NH_3 inhibit this action.

9. A direct measurement of recombinations of ions and of ions and electrons by a modified alternating field method. LAURISTON C. MARSHALL, University of California. Communicated by Leonard B. Loeb.—In analogy to the alternating field method for measuring ionic mobilities a method has been designed in which by a rotating sector a flash of x-rays in a nearly parallel beam from a 100 kv d.c. set is passed through the ionization chamber. At a varied time interval thereafter the ions are swept out by a high potential d.c. field and the charge is measured for a given number of cycles. This enables recombination to be measured over time intervals of from 5×10^{-4} seconds to 10 seconds and for computed ion concentrations from 10^7 ions/cm^3 to 10^4 ions/cm^3. Results on carefully dried air give the coefficient α as closely 1.2×10^6 which is nearly constant over time and concentration. The method is being applied to pure N_2 and H_2 where electrons are free for appreciable time intervals.

10. A study of the attachment of free electrons to neutral molecules in air and oxygen. AUSTIN M. CRAVATH, University of California.—The fraction h of the collisions between electrons and neutral molecules which result in attachment of the electron to form a negative ion has been measured throughout a considerable range of field strength and pressure in air and oxygen. A new and simple method was used which consisted in pulling electrons a given distance through the gas by means of an electric field, and then measuring the fraction still unattached by means of a grid having a high frequency alternating electric field between the adjacent wires. This grid removes the electrons, but permits the ions to pass through. From the fraction of the electrons still free and the electron mobility data of Townsend and Tizard, h was then calculated. In oxygen, h had a minimum at 0.9 volts average electronic energy and increased with either increase or decrease of the energy from this value. At constant energy, pressure had little effect. In air, h also rapidly increased as the electronic energy was reduced below 0.9 volts. This was the highest value at which reliable measurements were made. The variation with electron energy and the order of magnitude of the results ($h=10^{-6}$) are in agreement with Bailey. On the other hand, a rapid variation of h with pressure was found, while according to Bailey a change of pressure at constant electron energy has no effect. New and more direct proof of the permanence of the negative ions in weak fields, and evidence for the detachment of electrons from negative ions in high fields were also obtained.

11. The effects of an homologous series of amines on the mobilities of ions in hydrogen gas. LEONARD B. LOEB AND KARL DYK, University of California.—In discussion of the action of NH_3 gas on the mobilities of positive ions in H_2 gas and air Professor C. A. Kraus suggested that a study of the effect of primary amines might be of considerable interest. Studies of the mobilities in reasonably pure methyl amine CH_3NH_2 and *n*-propyl amine CH_3-CH_2-CH_2NH_2 have been made. The mobility in pure methyl amine is 0.51 cm/sec per volt/cm for the positive ion and 0.55 cm/sec per volt/cm on the old accepted basis, that in pure propyl amine at 74 mm reduced to N.T.P. is 0.25 cm/sec per volt/cm for the positive ion and 0.27 cm/sec per volt/cm for the negative ion. An addition of 0.27 percent of the methyl amine reduces the mobility of the positive and negative ions in H_2 from 5.94 cm/sec and 9.15 cm per sec. to 4.90 cm/sec and 7.01 cm per sec for positive and negative ions respectively. This is way in excess of the amount which the Blanc law of mixtures leads one to expect. In *n*-propyl amine the effect is even more striking for 0.26 percent of the amine in H_2. The values here fall from 6.38 cm/sec and 8.37 cm/sec to 3.77 cm/sec and 4.67 cm/sec. This indicates definite attachment of the amines to both ions in which the increased bulk of the molecules decreases the mobility markedly. In NH_3 the negative ion is affected just as in Blanc's law while the positive ion is increased in mobility to nearly the value of the negative ion.

12. Intensity Measurements in the Line Spectrum of Helium. W. C. MICHELS, California Institute of Technology.—By means of the photographic method described by Hodges at the Pomona meeting of the society, he and the author made a series of measurements on the intensities in the helium spectrum. The spectrum was emitted by a capillary discharge tube, excited by alternating current, at nine pressures, ranging from 1.92 mm to 34.3 mm of mercury. The absolute intensities of the thirteen lines measured show a maximum in the neighborhood of 2 mm to 5 mm pressure, dropping off rapidly below this and more gradually above. The position of this maximum shifts to lower pressures as we go to higher initial energy levels. As no correlation between these results and existing theory was apparent, the author, after modifying the method, has continued the work, with the spectrum excited by the controlled emission from a tungsten filament, in an attempt to isolate the affect of pressure variations from that produced by variations of the electron velocities at the time of impact.

13. O and N spectra in the extreme ultra-violet. D. C. SHELDON, Physical Laboratory, University of California. Introduced by F. S. Brackett.—By use of the method of grazing incidence with a concave speculum metal grating, spectra were observed for *O* and *N* down to 225A. A disruptive discharge through a π shaped discharge tube was used as a source. The plates were placed between the grating and the central image thus giving a very great dispersion. The dispersion increases with the wave-length from about 1.80 Angstroms per mm at 200A, to 1.25 Angstroms per mm at 450A.

14. The heat of dissociation of nitrogen. JOSEPH KAPLAN, University of California at Los Angeles.—Evidence is presented favoring a value of less than 9.1 volts for the heat of dissociation of nitrogen. The present argument is based on the assumption that the total energy in the D level of the molecule is only slightly greater than the energy in the D_0 level. The justification for this assumption is the absence of transitions other than the $D_0 - B_\pi$ transitions which arise when the fourth positive group is emitted. The energy of the molecule in the D_0 level is 14.8 volts so that a reasonable value for the total energy in the D level would be less than 15.0 volts. Making the statement that the products of dissociation in the D level are a nitrogen atom in the ^2D state and one in the ^2P state the resulting value for the heat of dissociation is 9.1 volts. The energy in the ^2D level is 2.4 volts and that in the ^2P level is 3.5 volts. If the total energies in the X' and A' levels of the molecule ion are calculated from this heat of dissociation they are found to be 26.0 and 23.6 volts respectively. The average of the observed values are 26.0 and 23.7 volts.

15. Revision of a former value of the specific charge of an electron, e/m. HAROLD D. BABCOCK, Mount Wilson Observatory.—In 1923 the ratio e/m was determined from the Zeeman effect produced on 116 spectral lines by magnetic fields of measured intensity. The result depended chiefly on lines well adapted to the purpose, but, due to lack of theoretical criteria for the selection of lines, some were occasionally used which are now known to be unsuitable and others which are not yet identified in multiplets. Recent progress in the analysis of the spectra of Cr and Ti permits a revision of the list of lines and the calculation of a new result free from the small errors formerly included. The weighted mean of 48 determinations is found, after correction for the latest value for the velocity of light, to be $e/m = (1.7606 \pm 0.0012) \times 10^7$ e.m.u./gram, practically the same as the former result, accidentally coincident with the observation of Houston, and very close to the value deduced by Birge, but distinctly lower than the results of most other investigators.

16. Some relationships between singlets and triplets in the spectra of two-electron systems. WILLIAM V. HOUSTON, California Institute of Technology.—The Darwin-Pauli theory of the magnetic electron provides a practical means of calculating the details of complicated spectra by the Schroedinger perturbation method. Applied to the simple case of two electrons in an arbitrary central field with one of the electrons in an s state, this gives the positions of the levels when the singlets and triplets are not widely separated. It is thus possible to predict the position of the singlet when the triplet is known. The consideration of the energy in an external magnetic field gives an expression for the Landé g factor which agrees with the observed values for the cases where the Landé formula is not applicable. Expressions are also derived for the

intensity of the intercombination lines, which show that these lines must be included if the sum rules are to be applicable. The intensities of these intercombination lines are roughly inversely proportional to the square of the separation of singlets and triplets, so that the observed intensity is usually due to the metastability of the upper state.

17. On the influence of collisions on the structure of Fraunhofer lines. ALBRECHT UNSÖLD, Mount Wilson Observatory. Introduced by Charles E. St. John.—As H. N. Russell, J. Q. Stewart, and others have shown, the absorption lines of the solar spectrum are mainly produced by resonance scattering. In order to explain the fact that the absorption lines are not perfectly black, but have a certain intensity at their centers, a further assumption is required. One must also take into account the influence of collisions (extinction of the resonance radiation and, as inverse process, thermal excitation). The differential equations of radiative equilibrium take then the most general form given by K. Schwarzschild (1914). For the central intensity I of a line one obtains:

$$I = B\left\{1 - \frac{1}{(1/2)\{\lambda + [\lambda(2+\lambda)]^{1/2}\}\{1+(3/2)\cos\theta\}}\right\}$$

B is the Kirchhoff-Planck function for the solar temperature; $\lambda/2$ the number of "extinguishing" collisions per lifetime of the excited state. The application of this theory to an atmosphere whose λ (proportional to pressure) decreases towards the top, explains the observation that in spectroheliographic images the center of a line corresponds to high levels, while the "wings" correspond to lower levels. Our assumptions are also fully confirmed by numerous other observations, such as difference of the lines between center and limb of the sun; differences between the spectra of giant and dwarf stars.

18. Polarization of the L_{β_1} radiation of tungsten. PAUL KIRKPATRICK AND IWAO MIYAKE University of Hawaii.—The radiation investigated was reflected from 210 planes of rock-salt in the first order, at an angle $\theta = 30°\ 30'$. The reflected intensity was measured by ionization, with the x-ray tube placed successively in positions parallel and perpendicular to the plane of reflection. From the ratio of these two reflected intensities the polarization of the reflected radiation may be deduced, as one of us has previously shown (Phys. Rev., **29**, 1927). Reflected intensities were measured by sweeping the crystal through the position of reflection and noting the total resultant ionization. Variations in reflected intensity from causes other than polarization were checked out by the use of a separate, stationary ionization chamber receiving the radiation directly transmitted by the crystal. By measuring the polarization of the characteristic line, together with its associated general radiation, and measuring separately the polarization of the general radiation near to the line, it was possible to deduce the polarization of the characteristic radiation alone. A mean of several determinations resulted in the value 1.002 ± 0.017 for the ratio of the mutually perpendicular electric vectorial components of intensity in the L_{β_1} radiation. Within the limits of these observations, therefore, this radiation is unpolarized. The maximum potential applied to the x-ray tube was 70 kilovolts, and the tube current 3.25 milliamperes.

19. The ultra-violet light of the sun as the origin of auroras and magnetic storms. H. B. MARIS AND E. O. HULBURT, Naval Research Laboratory.—It is assumed that the sun, when active, emits a sudden (1/2 hour) blast of ultra-violet light. For example, if 1/10,000 part of the solar surface, normally at a temperature of 6000°, were removed and there were exposed the black-body radiations at 30,000°, the solar constant would be increased by 1 percent (as is observed) and the ultra-violet energy, λ500 to 1000A, by 10^6. This ultra-violet energy, completely absorbed in the high lying (200 km) atmospheric gaseous layers, blasts out these layers to produce ions up to 40,000 km. Due to gravity and the earth's magnetic field the first effect of the high flying ions is to produce a sudden current, 10^6 amperes, in planes parallel to the equator, which causes a magnetic field 10^{-3} gauss simultaneously over the whole earth, as is observed in the first phase of the world-wide magnetic storms. Numbers of ions descend to the zones 23° from the magnetic poles and form there diamagnetic concentrations of considerable intensity (also give rise to the auroras). On the assumption that the blast of ultra-violet light does not die away abruptly but continues with lessening intensity for a day or so, the dia-

magnetic concentrations wax with the day and wane with the night. The changes in the earth's magnetic field caused by this diamagnetism are found to agree in nearly every detail with the observed complicated diurnal storm variations in the three magnetic field components at all latitudes.

20. What is the moon made of? PAUL S. EPSTEIN, California Institute of Technology.—The writer is indebted to Messrs. Nicholson and Pettit of Mt. Wilson Observatory for admirable observational material on the change of temperature of the moon during a lunar eclipse. Theoretically the decrease of temperature for the initial phase of the eclipse should follow the law $\Delta T = -4At^{3/2}/3t_0(\pi\kappa\rho c)^{1/2}$. A denotes the insolation in the beginning, t the time counted from a moment a few minutes after the setting in of the eclipse, t_0 the duration of the penumbra stage, κ heat conductivity, ρ density, c specific heat of the material of the moon surface. Comparison with Nicholson and Pettit's curve gives for $1/(\kappa\rho c)^{1/2}$ a value in the neighborhood of 120. For terrestrial materials this coefficient has the following values: granite 16, basalt 24, quartz sand 58, cellite 90, pumice stone from 100to 150. It follows that the surface layer of the moon could not be made of any solid rock known on earth but must consist of some highly porous material comparable in its thermic qualities to volcanic ashes.

21. Settling of gases and constitution of the atmosphere. PAUL S. EPSTEIN, California Institute of Technology.—There are two processes going on in the atmosphere: (a) diffusion in the gravitational field of the earth which tends to produce a concentration of each constituent gas according to the barometric law; (b) a violent stirring action due to convection currents. The time element of the diffusion process was investigated; it is controlled by an equation of the type $\partial u/\partial t = a^2x^{-m}\partial^2 u/\partial x^2$, a complete theory of which was developed. If we start from a state in which the atmosphere contains a small uniform percentage of hydrogen, the time necessary for the hydrogen to come near the equilibrium distribution in the absence of convection currents turns out to be large compared with 10000 years. In a period of 10 years the concentration will not change more than 0.3 percent. For heavier gases the periods involved are still larger. We must conclude that for the lower parts of the atmosphere (troposphere) the stirring process is the more powerful one, and that their constitution is essentially uniform, apart from local contaminations. Concentrations according to the barometric law will set in at higher levels where the density is too small for vigorous convection.

22. A new treatment of vortex motion. H. BATEMAN, California Institute of Technology. —An investigation in which the component velocities (u, v, w) of a particle of fluid are represented by expressions of type $u = \partial\phi/\partial\kappa - \dot{s}\partial s/\partial x$ where $\dot{s} = ds/dt$ and s and ϕ are functions of x, y, z and t. A generalization of Bernoulli's equation is obtained which, for the case of steady motion, is of type

$$p/\rho + (u^2+v^2+w^2+s^2)/2 = \text{constant}.$$

This equation accounts for the losses of head in the wake of an airfoil.

23. On the assumptions of matrix mechanics. BORIS PODOLSKY, University of California. —An investigation of the assumptions of the matrix mechanics shows that it is possible to derive all essential properties of matrices from a single physical assumption. This assumption may be stated as follows: Corresponding to any mechanical system there exists a matrix scheme in which matrices corresponding to dynamical variables satisfy the same equations as the dynamical variables themselves do classically, except that instead of the commutative law of multiplication $xy - yx \equiv (hi/2\pi)[x, y]$, where $[x, y]$ is the usual Poisson bracket expression. The method of constructing these matrices, with the help of certain functions, is derived, and these functions are shown to satisfy Schrödinger differential equation. The properties of the matrices follow: (1) matrices corresponding to coordinates and momenta satisfy the Heisenberg-Dirac quantum conditions; (2) matrices satisfy the equation of motion of Heisenberg's mechanics; (3) in a system with well ordered Hamiltonian matrices of well ordered functions are Hermitian; (4) for a conservative system the matrix of the Hamiltonian is diagonal; and (5) for a conservative system matrix elements have the form $c(a'a'')\exp\{2\pi i[E(a') - E(a'')]t/h\}$ where $c(a'a'')$ is a constant and $E(a')$ and $E(a'')$ are the characteristic values of the energy. This paper may be regarded as a development of Dirac's transformation theory. For a physical interpretation of matrices further assumptions are required.

24. Protonic spin. BENEDICT CASSEN, California Institute of Technology.—It is shown that Dennison's theory of the rotational specific heat of hydrogen is not evidence for assigning spins and antisymmetric wave functions to protons. It is found that his theory in conjunction with evidence obtained from nuclear structure lead to the assignment of symmetric wave functions and the absence of spin to protons.

25. Quantum defects for non-penetrating orbits. LINUS PAULING, California Institute of Technology.—The contribution of polarization of the atomic core to the quantum defect for "non-penetrating" orbits of alkali-like atoms and ions has been calculated with the use of the quantum mechanics equation and the known values of the core polarizabilities (Pauling, Proc. Roy. Soc., **A114,** 181 (1927). The calculated values are smaller than the observed quantum defects by an amount which decreases for successive series in the order $p > d > f$, etc., and which increases for isosteric ions with increasing degree of ionization; for example, in the order $Li_I < Be_{II} < B_{III} < C_{IV}$. It is further shown by the application of the first order perturbation theory that even for these orbits penetration of the atom core is not negligible. Values of the quantum defect calculated by taking into account both penetration and polarization of the atom core are in good agreement with those observed.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session in the Auditorium after the completion of the regular program for the session.

26. Shot fluctuations in wave mechanics. BENEDICT CASSEN. California Institute of Technology.—It is shown that the Born-Dirac interpretation of the transformation functions of quantum mechanics allows for fluctuations in time in a stationary state but gives no information about these fluctuations. The Schroedinger interpretation excludes such "shot" fluctuations in what Weyl calls a "pure state" so that they can only occur in a superposition of pure states in various phase relationships. It is shown that such superposition of waves can explain shot effects without assuming any inherent fluctuation in a stationary state.

27. Spectral intensities of non-harmonic and aperiodic systems. BENEDICT CASSEN, California Institute of Technology.—A general formula is derived for the intensity of radiation in a quantum jump in any kind of quantum dynamical system. The total energy radiated by s, t jumps is

$$P(s,t)=\frac{2e^2}{3m^2c^2}\left|\iiint\left[\left(\frac{\partial V}{\partial x}\right)^2+\left(\frac{\partial V}{\partial y}\right)^2+\left(\frac{\partial V}{\partial z}\right)^2\right]^{1/2}\psi_s^*\psi_t\,dxdydz\right|^2$$

where V is the potential energy function for the system. For the intensity of s, t radiation in the l, m, n direction we get

$$I_{l,m,n}(s,t)=\frac{e^2}{4\pi m^2\nu^2c^3}\left[\left|\iiint\left[\left(\frac{\partial V}{\partial x}\right)^2+\left(\frac{\partial V}{\partial y}\right)^2+\left(\frac{\partial V}{\partial z}\right)^2\right]^{1/2}\right.$$

$$\left.\psi_s^*\psi_t\,dxdydz\right|^2-\left|\iiint\left[2\frac{\partial V}{\partial x}+m\frac{\partial V}{\partial y}+n\frac{\partial V}{dz}\right]\psi_s^*\psi_t\,dcdydz\right|^2\Bigg]$$

The Heisenberg amplitude rule is only strictly applicable to an harmonic oscillator.